Selecting Research Locations on Mars

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Sept. 8, 2004

Mars Exploration Rover Mission

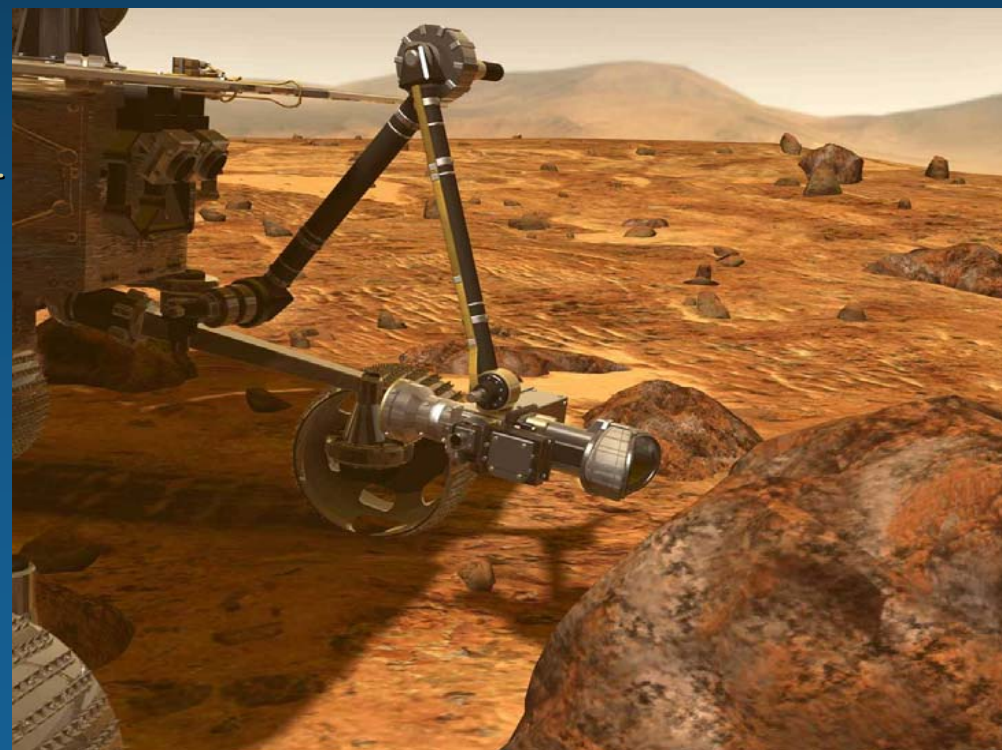
- Twin Mars missions with robotic field geologists
- Main focus: study history of water on Mars ("Follow the water")
  - … by studying rocks and soils that hold clues to past water activity.
  - Landers landed at sites that appear to have held liquid water in the past.
- Launched: June, 2003
- Landings: January, 2004
- Rover mission duration: 6 months and counting!

Mars Exploration Rover Mission

- ~ 7 month cruise to Mars
- Landers used airbags to land and bounce to a stop.
- Rovers first took panoramic images to determine where to go.
- Rovers can drive up to 100 yards per day.
- Spirit has driven almost 2 miles.
- Rovers are equipped with stereo cameras, science instruments, robotic arm (with "wrist" and "elbow").

MER Science Instruments

- Panoramic Camera (PanCam)
  - Determine mineralogy, texture, and structure of the local terrain.
- Various Spectrometers
  - Identify rocks and soils of interest.
  - Determine rock-forming processes.
  - Analyze mineralogy and elemental abundance.
- Magnets
  - Collect magnetic dust particles.
- Microscopic Imager
  - Obtain close-up, high-resolution images of rocks and soils.
- Rock Abrasion Tool (RAT)
  - Remove dusty and weathered rock surfaces.



MER Science Goals

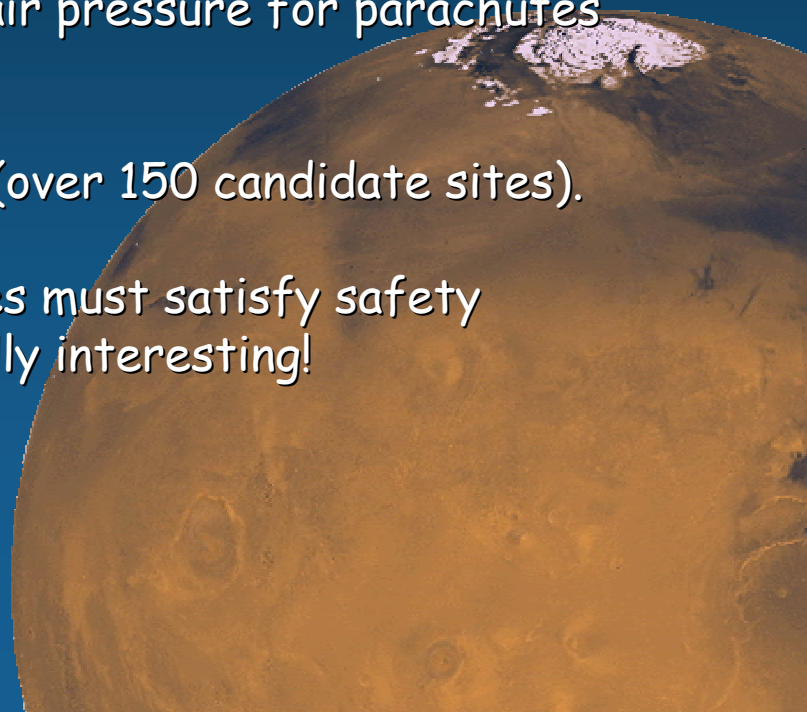
- Determine whether life ever arose on Mars.
  - its past, where it was located, chemical and geological interactions w/ rocks and soil.
- Characterize the climate of Mars.
  - Studies of rock samples will reveal past climate, which may have been warmer and wetter.
- Characterize the geology of Mars.
  - With particular interest in iron-bearing minerals (e.g. hematite).
- Prepare for human exploration.
  - Identify potential hazards to humans.
  - Assess potential for resources for human missions.
  - Improve designs for future human-operated vehicles.

MER Science Goals: Geology

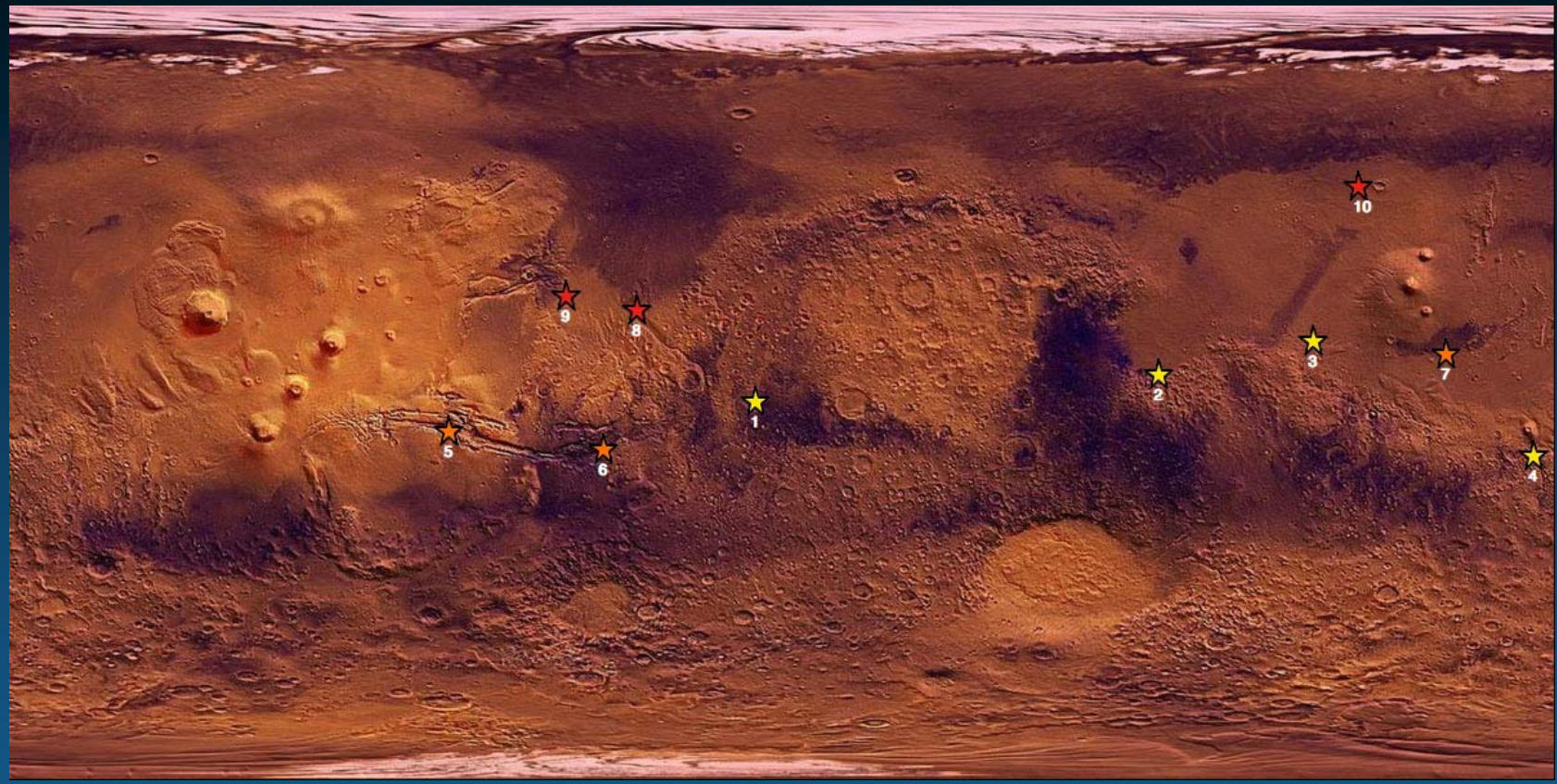
- Search for rocks that hold clues to past water activiy.
- Determine composition of minerals, rocks, and soils around landing sites.
- Determine the processes that have shaped terrain and influenced chemistry.
  - (e.g. water and wind erosion, sedimentation, cratering, volcanism, hydrothermal processes)
- Validate observations made by orbiters (provide "ground truth").
- Search for iron-bearing minerals.
- Search for geological clues to environments that existed when liquid water was present.
  - Assess if those environments were conducive to life.

Landing Site Constraints

- Near equator, for adequate solar power.
- Not too windy.
- Not too rough or rocky.
- Gentle slopes.
- Lower elevations, for enough air pressure for parachutes to function.
- 5% of Mars surface qualifies (over 150 candidate sites).
- Winning landing site candidates must satisfy safety constraints and be scientifically interesting!



Mars Landing Sites



Top Choices for MER 2003:

1. Meridiani Planum
2. Isidis Planitia
3. Elysium Planitia
4. Gusev Crater

Previously Considered:

5. Melas Chasma
6. Eos Chasma
7. Athabasca Vallis

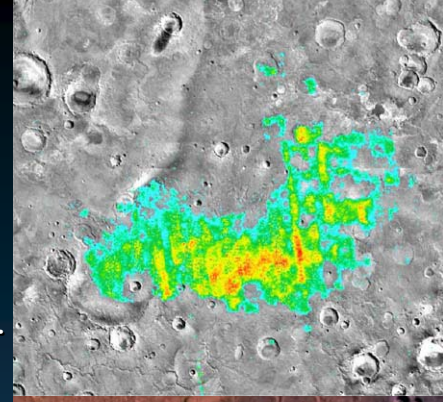
Past Landing Sites:

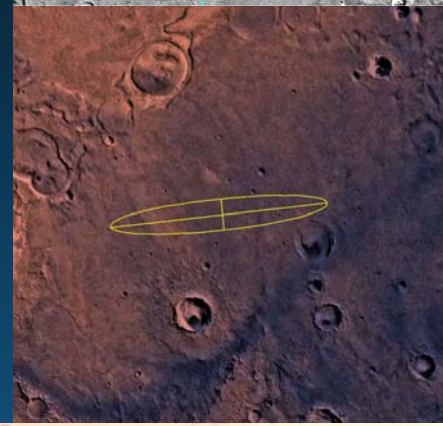
8. Pathfinder (Ares Vallis)
9. Viking 1 (Chryse Planitia)
10. Viking 2 (Utopia Planitia)

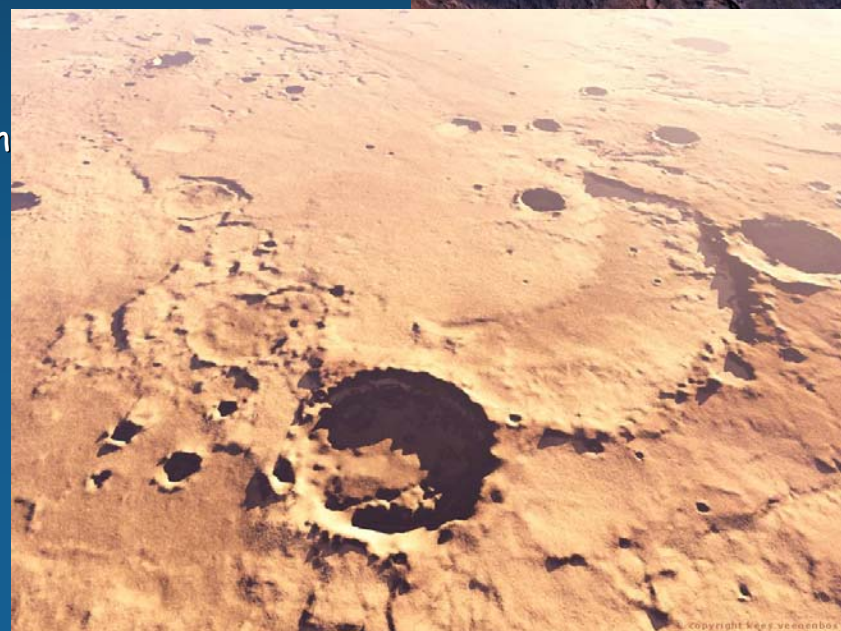
Meridiani Planum

- Located in ancient southern highlands, near equator.
- A high plain located in a very old multi-ringed impact crater from very early in Mars' geologic history.
- Contains dark gray iron oxide called hematite.
  - Forms in hot springs or standing bodies of water, or
  - Formed by hydrothermal water altering volcanic rock.
  - Thus, strongly suggests presence of water.
- Or... it could have formed under special hot and dry conditions in which basalt can rust.
- "Meridiani": close to prime meridian
  "Planum": high plain
- ***Selected!***

Watch Flyover

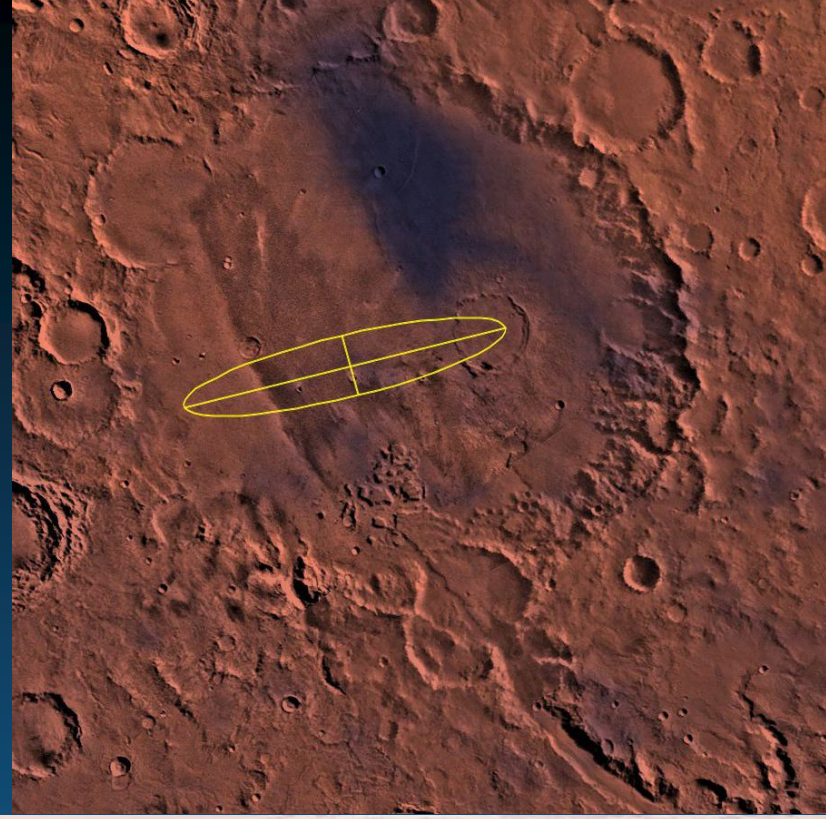


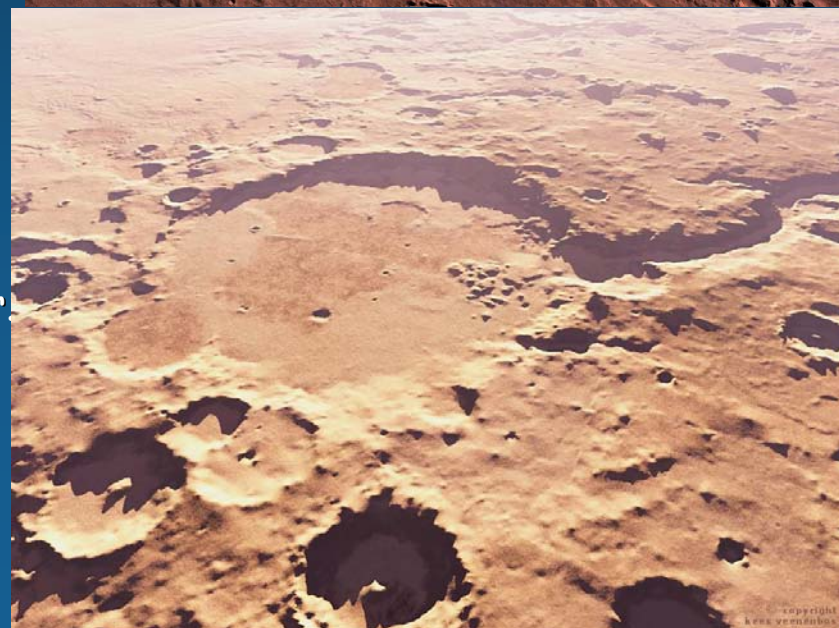




Gusev Crater

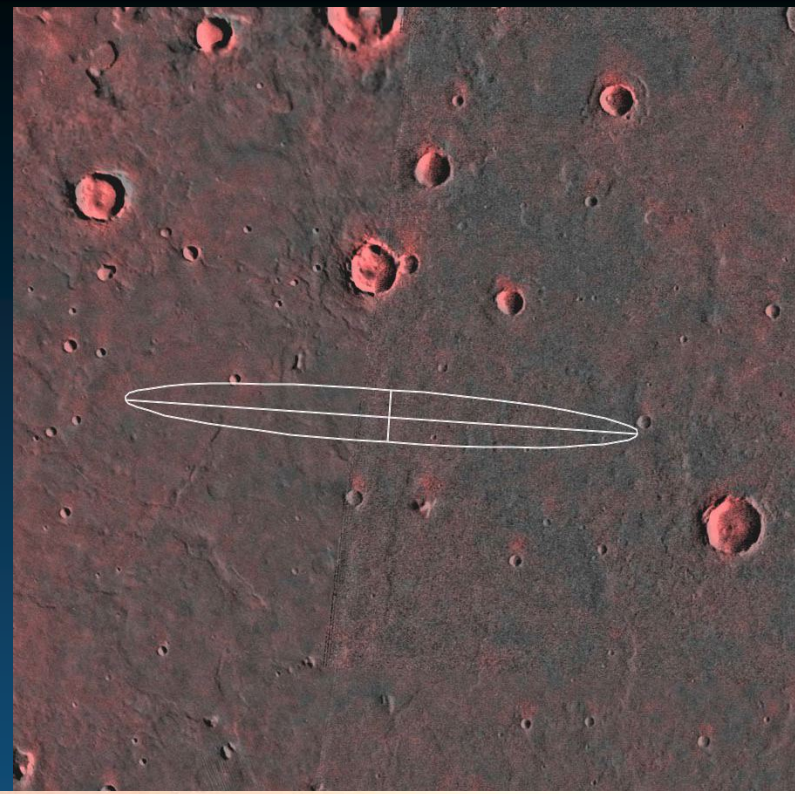
- Located near boundary of ancient highlands and younger lowlands.
- Inside a large, very old impact crater.
- A lake may have formed here, from water flowing from a large valley (Ma'adim Vallis), providing an environment conducive to life.
- Or... floor might be covered with lava and ash which conceals information about water.
- Named for a Russian astronomer.
- ***Selected!*** ***Watch Flyover***

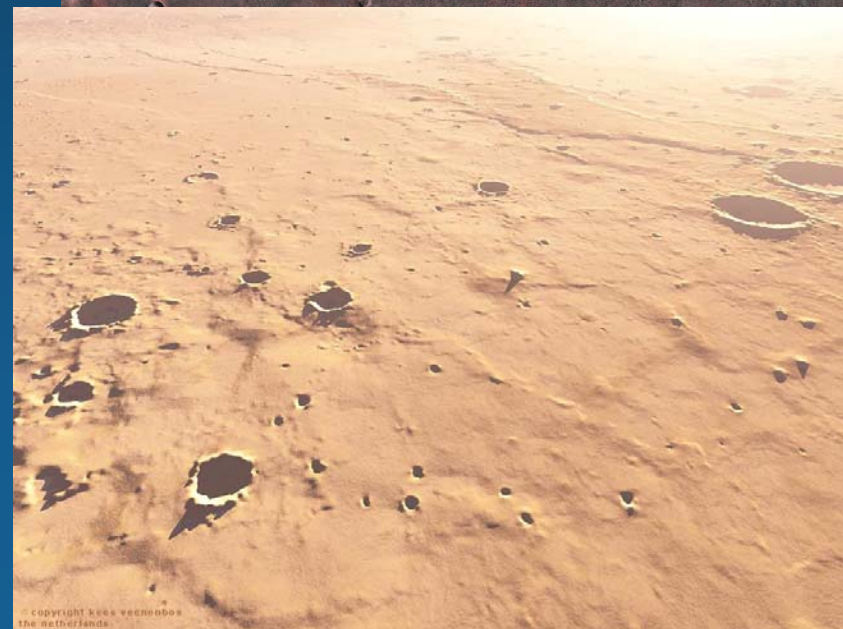




Elysium Planitia

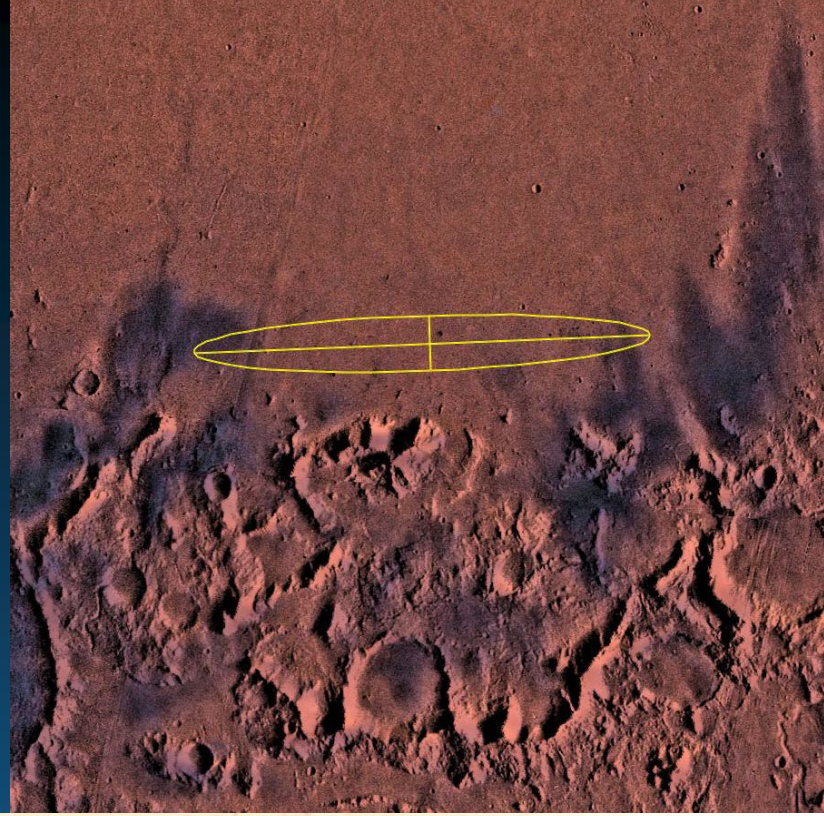
- Located in northern lowlands in a region that once may have been covered by a large ocean.
- Ancient marine sediments may have washed down from adjacent highlands.
- If once covered by an ocean, there may be evidence of past microbial life.
- Or… simply smooth volcanic plains.
- "Elysium": final resting place of virtuous souls
  "Planitia": low plain





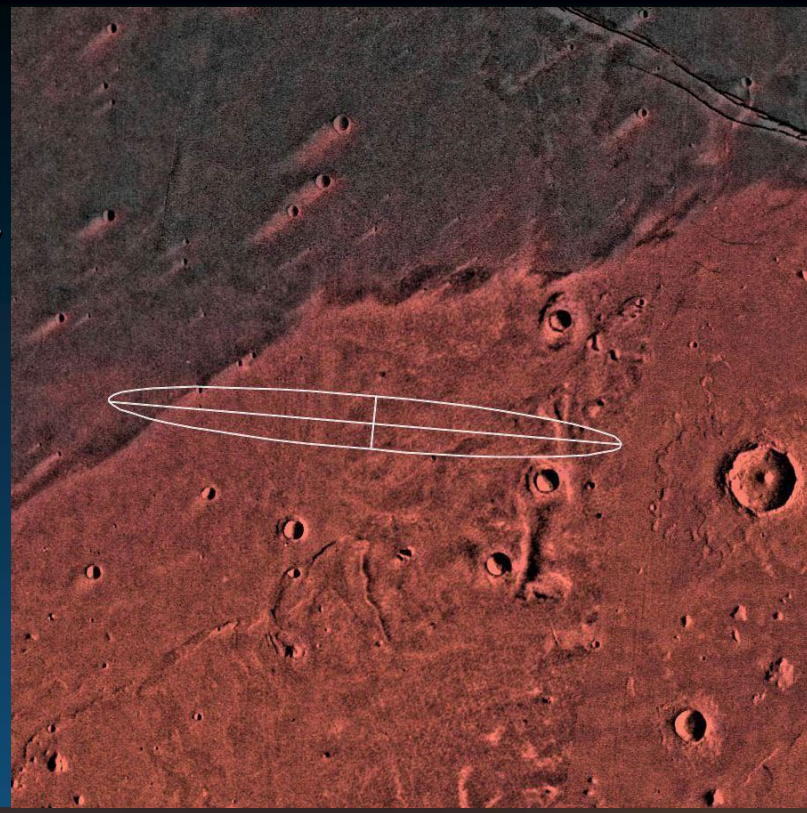
Isidis Planitia

- Located in smooth plain near the equator, next to ancient highlands.
- Beagle 2 Mars lander (on Europe's Mars Express) will land close to here.
- Likely composed of sediments washed down from the highlands by river valleys.
- Or… smooth plains could be volcanic ash or an ancient lava flow.
- "Plains of Isidis": Isis is Greek name for Egyptian goddess of motherhood and fertility. Watch Flyover



Athabasca Vallis

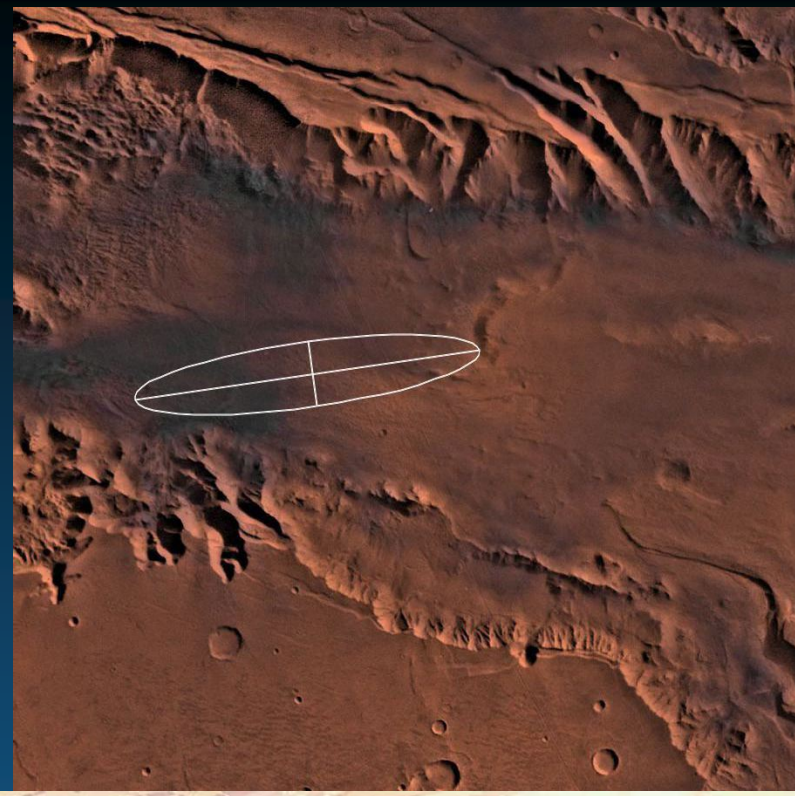
- Located on the floor of a giant flood-carved channel, one of many on Mars.
  - This is one of the youngest and best preserved.
- Evidence points to carving by release of warm, subsurface hydrothermal fluids, which may have harbored life.
- Or... it may have been carved by cold, near-surface water.
- Dangerous mesas and impact craters near edge of target zone, and possibly rocky channel floor, preclude a safe landing here.
- Named after longest river in Alberta, Canada.



Melas Chasma

- A relatively flat region within Vallis Marineris, largest canyon system in the solar system.
- Deposits at this site are possibly from an ancient lake that formed within the canyon system.
- Or... deposits could be landslide material from surrounding canyon walls.
- Winds at this site are too high for safe landing.
- "Melas": Greek word for dark; it is a noticeably dark patch through telescopes.

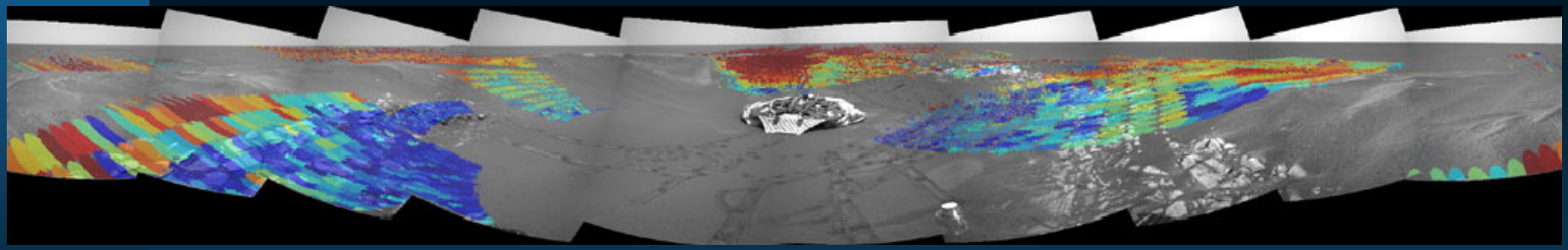
Watch Flyover

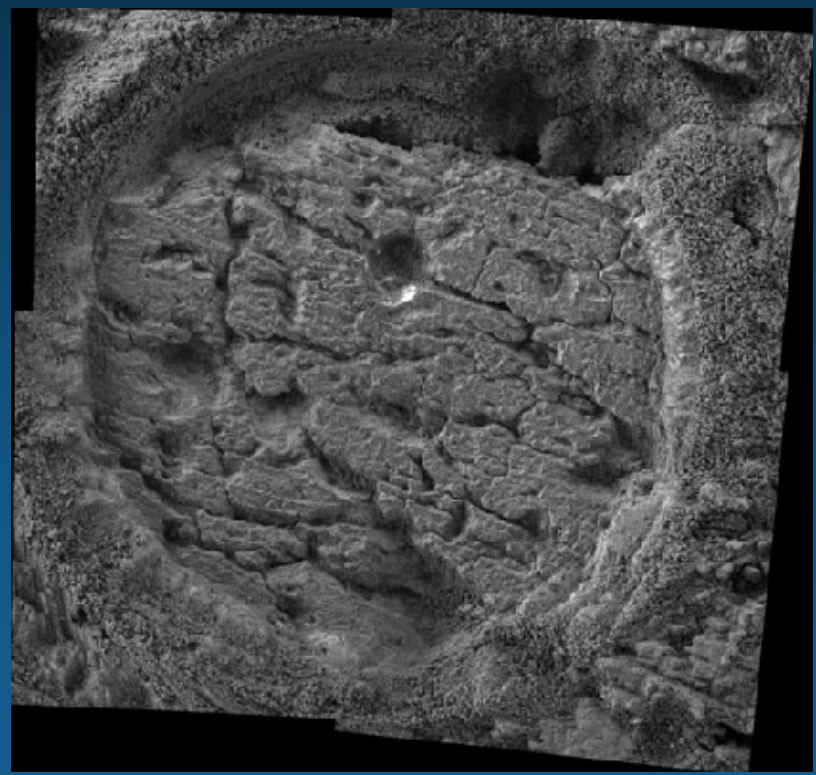


MER Science Results: Opportunity

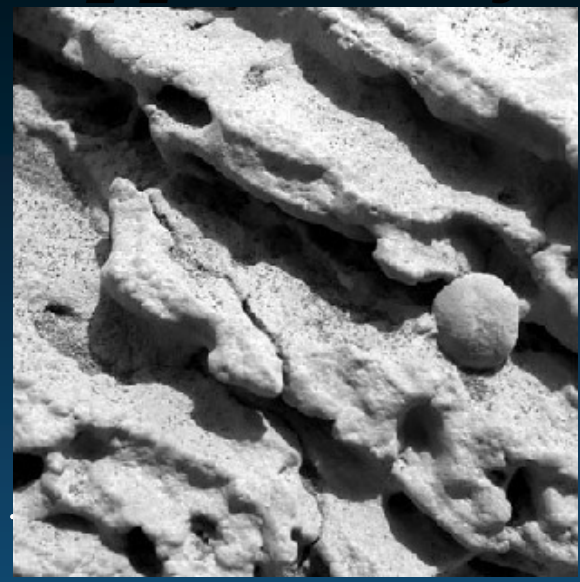
- Opportunity landed…
  - in Meridiani Planum.
  - in a small impact crater about 20 yards across.
  - next to an outcrop of layered rock (***lucky!***)

MER Science Results: Opportunity

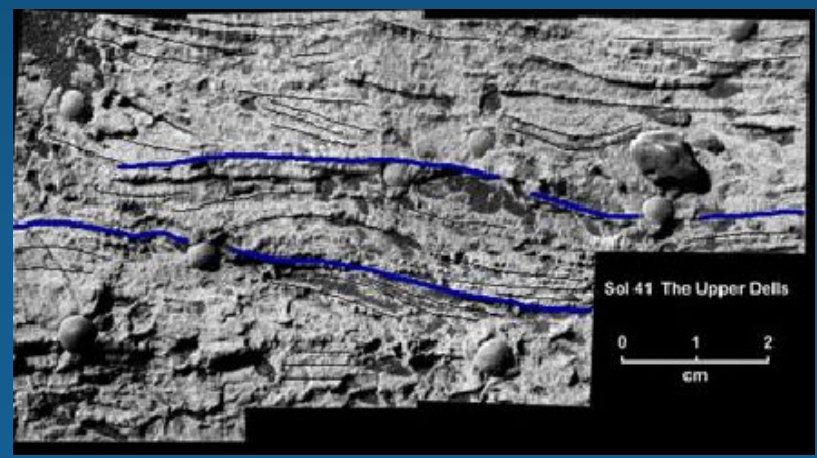




MER Science Results: Opportunity



- "Blueberries"
  - Formed as outcrop is sandblasted.
  - More resistant blueberries fall out and roll down.
- Outcrop was soaked with water in
  - Blueberries are concretions.
  - Presence of sulfur and mineral called jarosite.
- Rocks probably deposited in gently-flowing water.
  - Cross-bedding and ripple features.

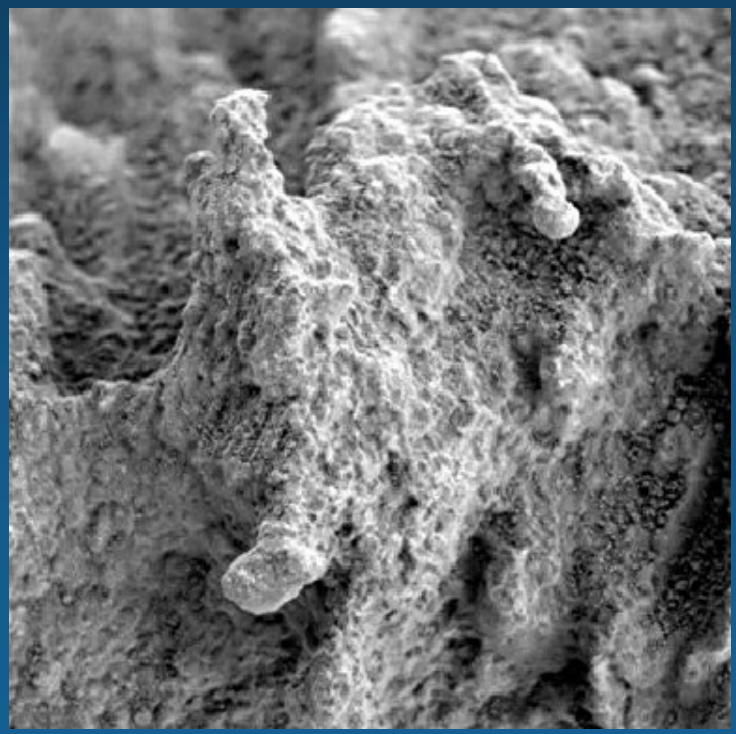


MER Science Results: Spirit

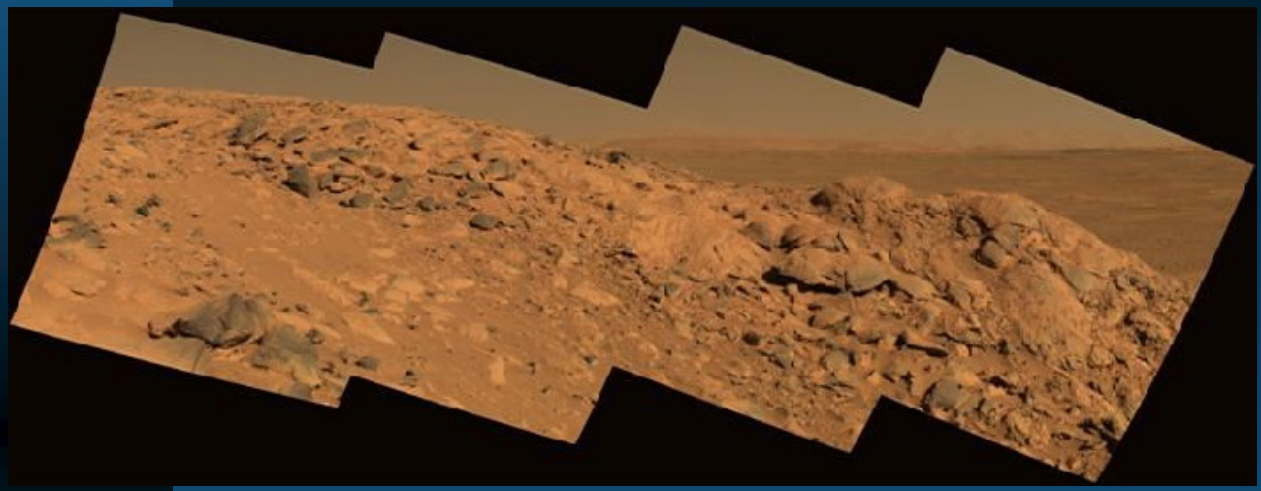
- Spirit landed in Gusev Crater.
- First looked at rock "Adirondack".
- Rocks are mainly volcanic (basalt, like Meridiani).

MER Science Results: Spirit

- After trekking about 1.5 miles towards hills…
- Found odd-shaped rock containing hematite.
- Found rocks that appear to have been chemically altered through interaction with liquid water.
  - High levels of bromine, sulfur, chlorine.



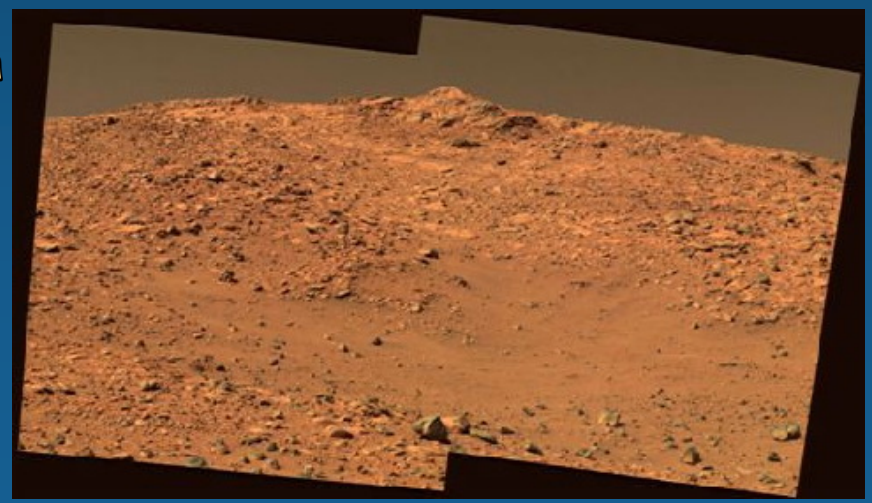
MER Science Results: Spirit



Key MER Science Results

- Mariner 9 had shown that water once flowed on surface.
- Goal of MER science mission
  - Find rocks that formed in liquid water.
  - Determine the ability of thei environments to support life.
- Key finding

  Strong evidence for rocks being formed in water in a way which may have supported microbes.



Marsoweb: Why It's Needed

- Spring '99: Focus was on Surveyor 2001 Rover mission. (since cancelled)
- A focal point for coordinating landing site studies was needed…
  - to promote interaction of planetary scientists.
  - to provide a Web-based resource center for landing site materials.
- Collaborators:
  - NASA Ames Center for Mars Exploration (CMEX)
  - Exploratory Computing Environments Group at NAS:
    NASA Advanced Supercomputing Facility
  - Jet Propulsion Lab's Mars Surveyor Project Office

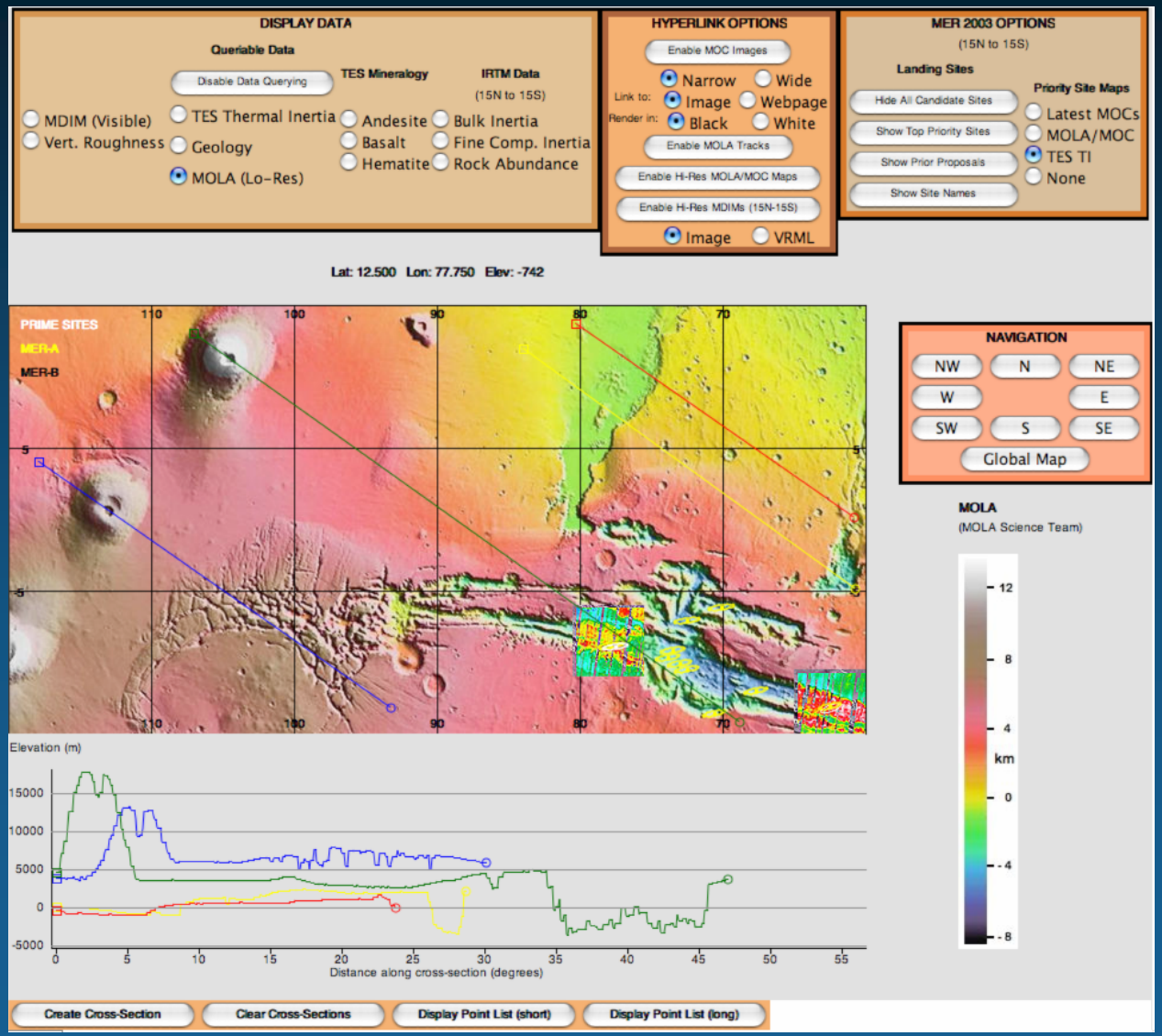
Marsoweb: What It Does

marsoweb.nas.nasa.gov

- Web environment for online analysis of Mars orbiter data
- Goals:
  - Facilitate landing site selection for Mars rover missions.
  - Provide interface to orbiter data for general Mars studies.
- Central repository for memoranda, maps, data, images for potential landing sites.
- Emphasizes ease-of-use and interactivity.

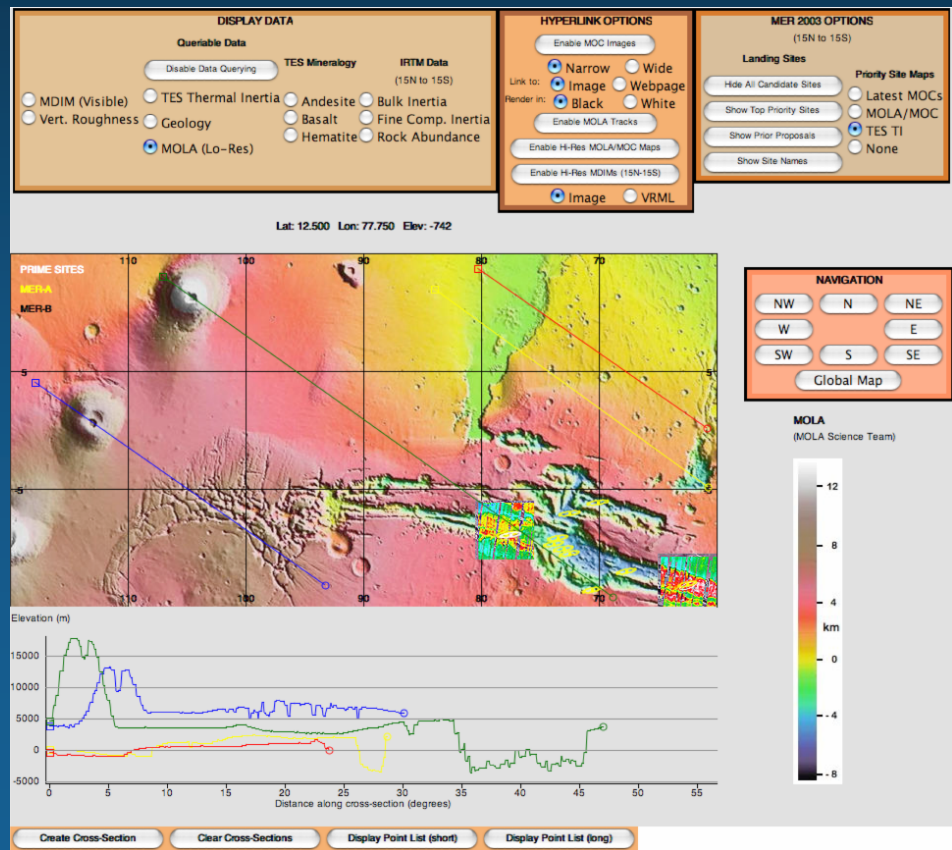
Data Map Viewer

Java applet for viewing and querying landing sites, data, and maps



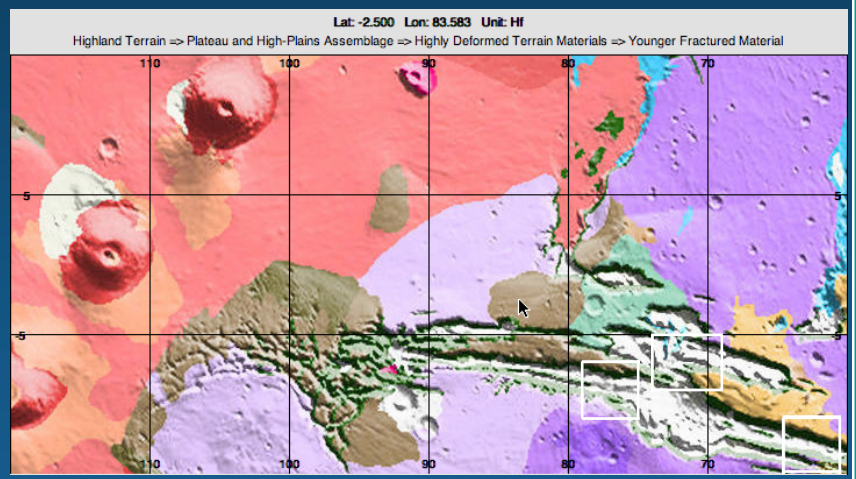
Interactive Global Data Archive

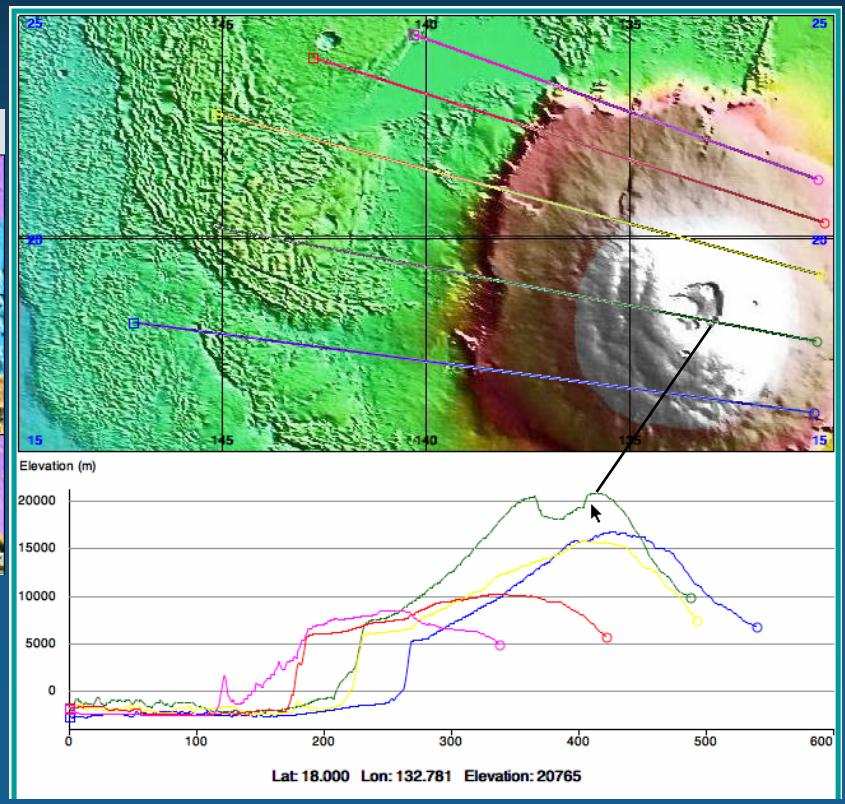
- Facilitates data discovery, cross-comparison of orbiter data.
- Includes:
  - MGS Mars Orbiter Laser Altimeter (MOLA): Elevation
  - MGS Thermal Emission Spectrometer (TES): Thermal Inertia
  - MOLA-derived Vertical Roughness
  - TES-derived Mineralogy
  - Viking Infrared Thermal Mapper (IRTM) Data
  - Digital Maps of Geology Units



Interactive Data Maps

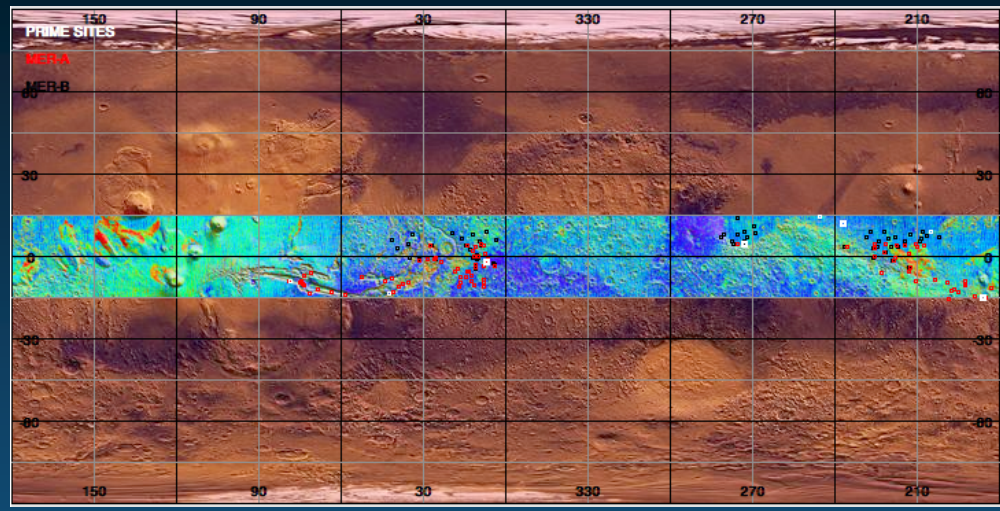
- Data display for elevation, thermal inertia, and geology maps.
- Profile creation from user-drawn cross-sections

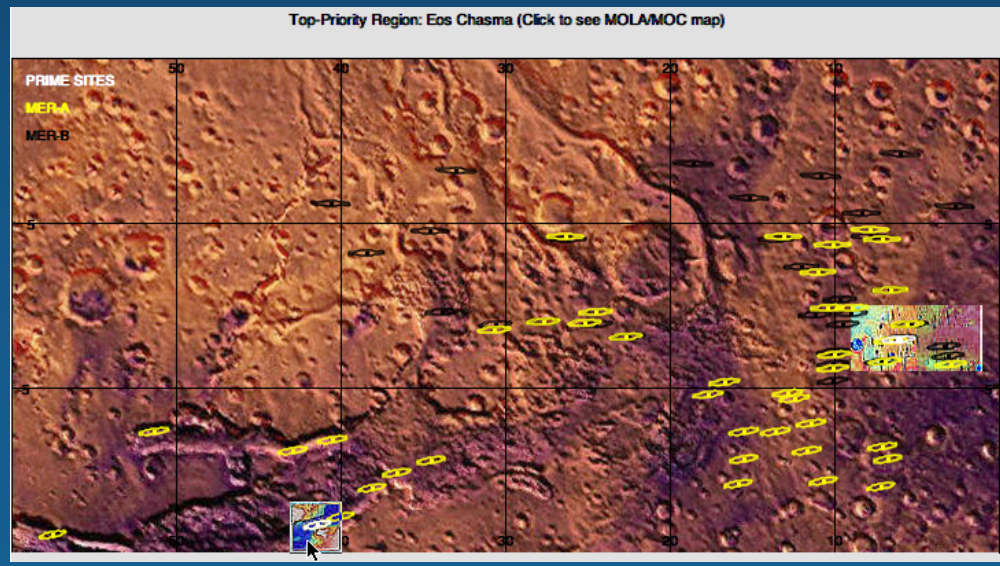




MER Landing Site Resources

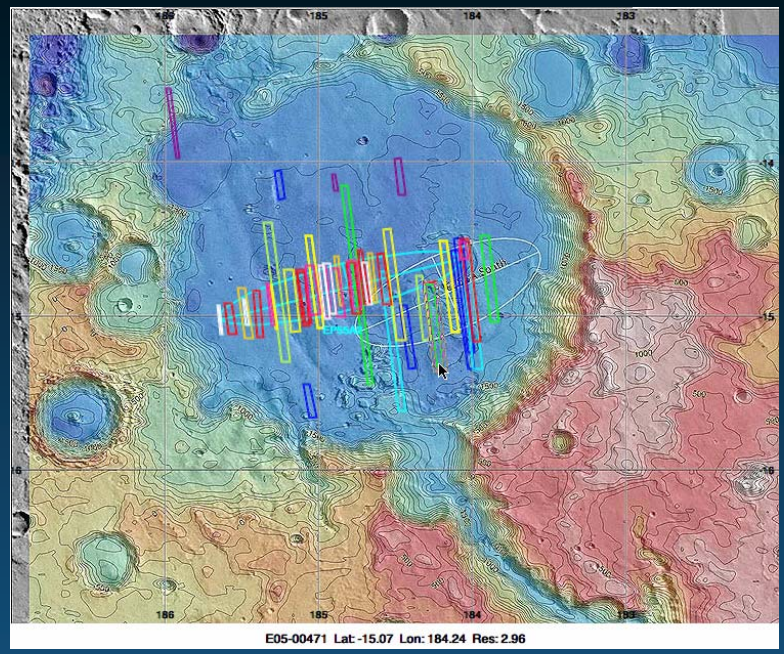
- Repository of talks, memoranda, engineering data, etc.
- Landing site candidates
  - Abstracts, etc.
- Interactive data maps
- High-resolution site maps and images
- 3D VRMLs of sites
  - Data & images mapped onto terrain data

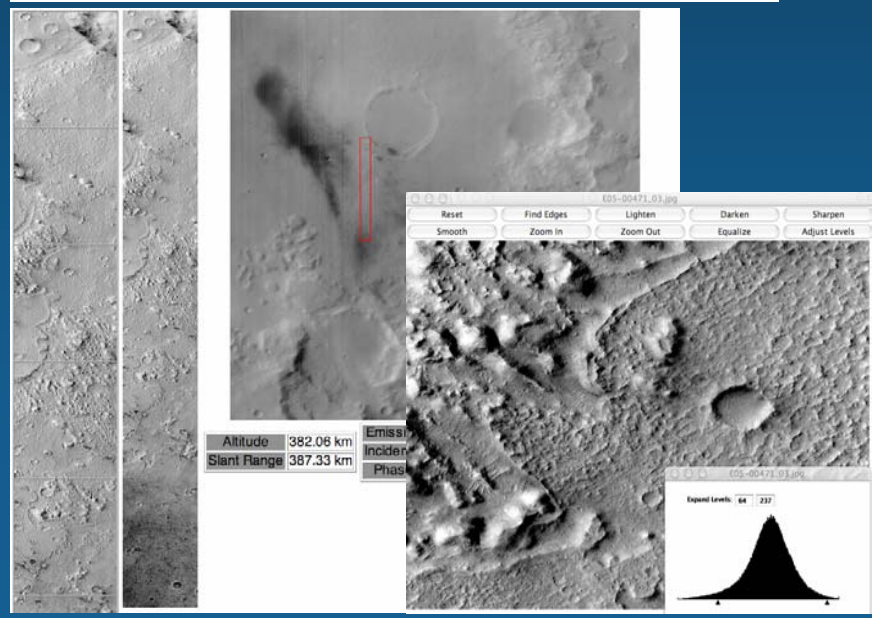




Mars Orbiter Camera Images for MER

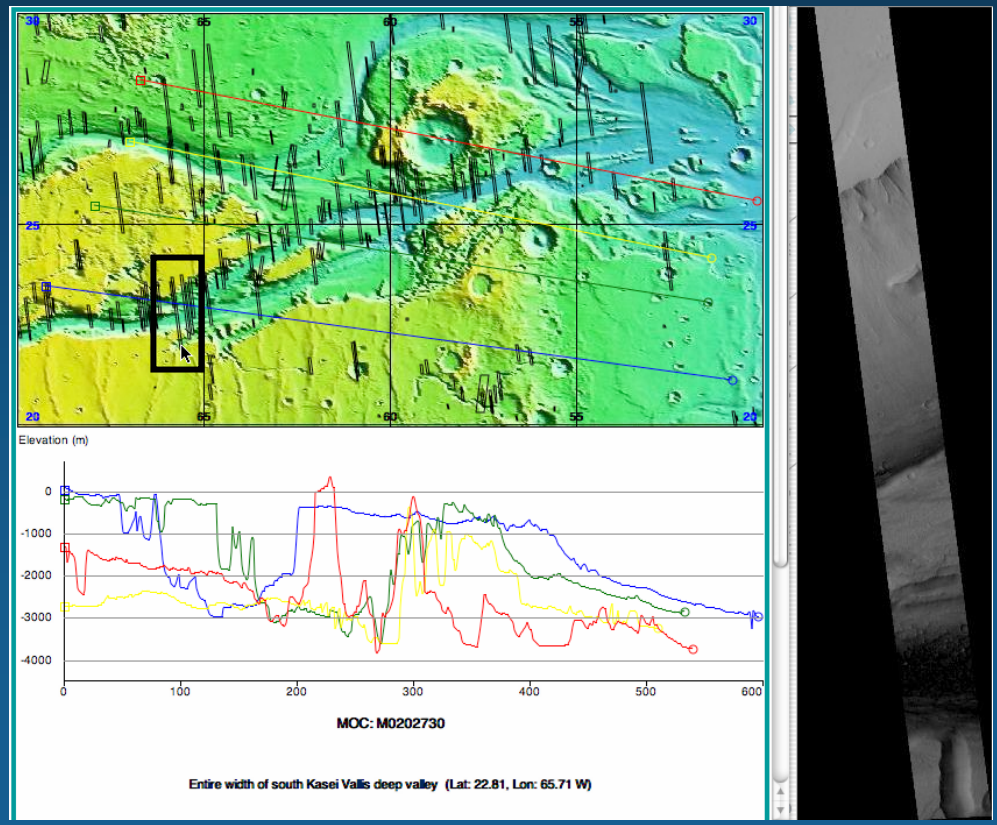
- MOC: Mars Orbiter Camera (~ 3 meters/pixel resolution)
- > 460 MOC images of candidate landing sites
- Graphical navigation via regional imagemaps
- Each MOC image webpage has:
  - Optimized images
  - "Context images" (wide-angle MOC images)
  - Online image processing:
    - histogram editing, EQ
    - zooming, cropping
    - sharpening
    - noise filtering (future)





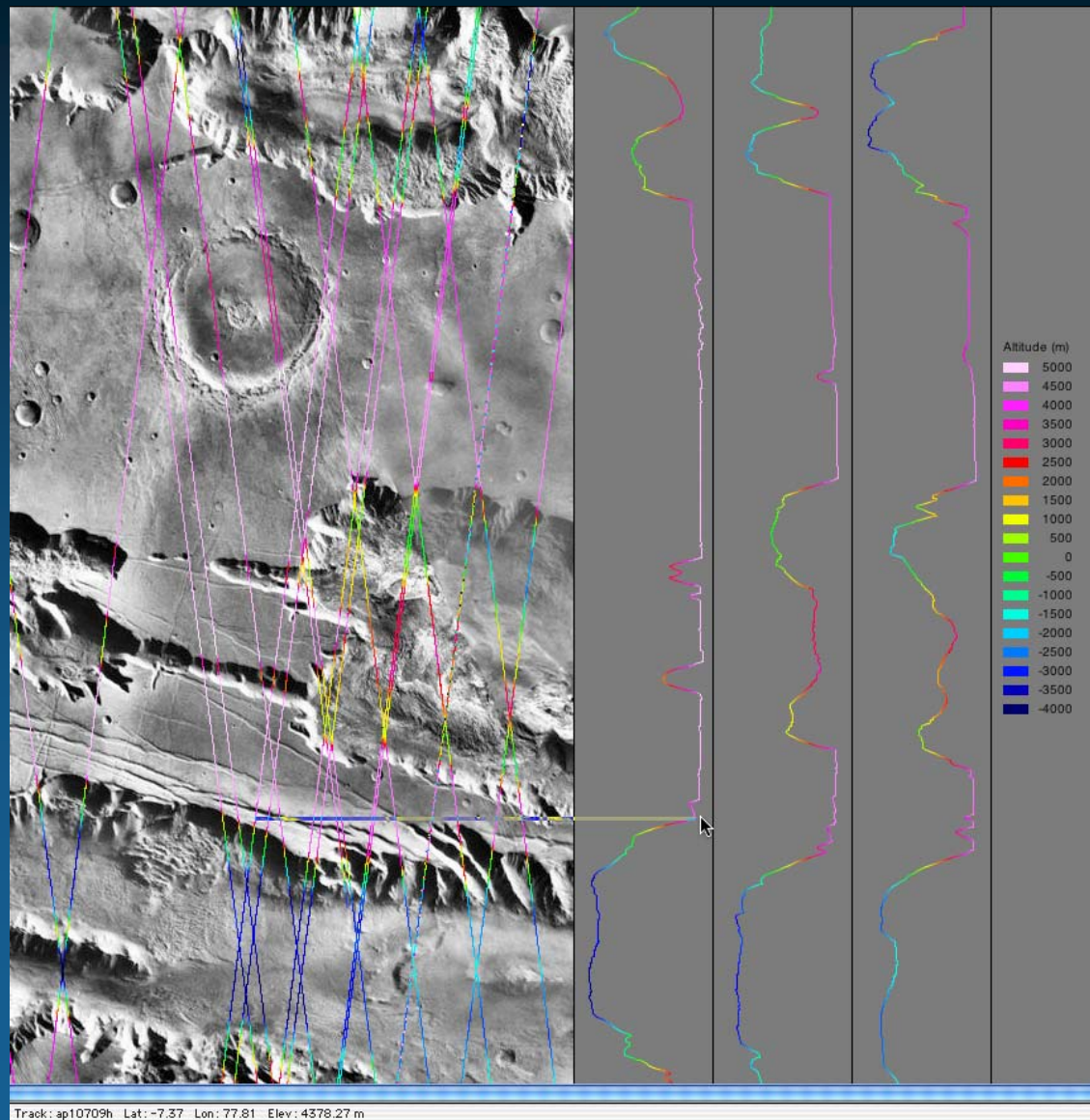
Mars Orbiter Camera Images (General)

- Graphical navigation of over 110,000 high-resolution MOC images
  - 3 to 15 meters / pixel (narrow-angle MOCs)
  - Housed at Malin Space Systems
- Local Marsoweb store of ~ 1000 images from aerobraking phase
  - "Hand-placed" on Viking context images
  - Online image processing



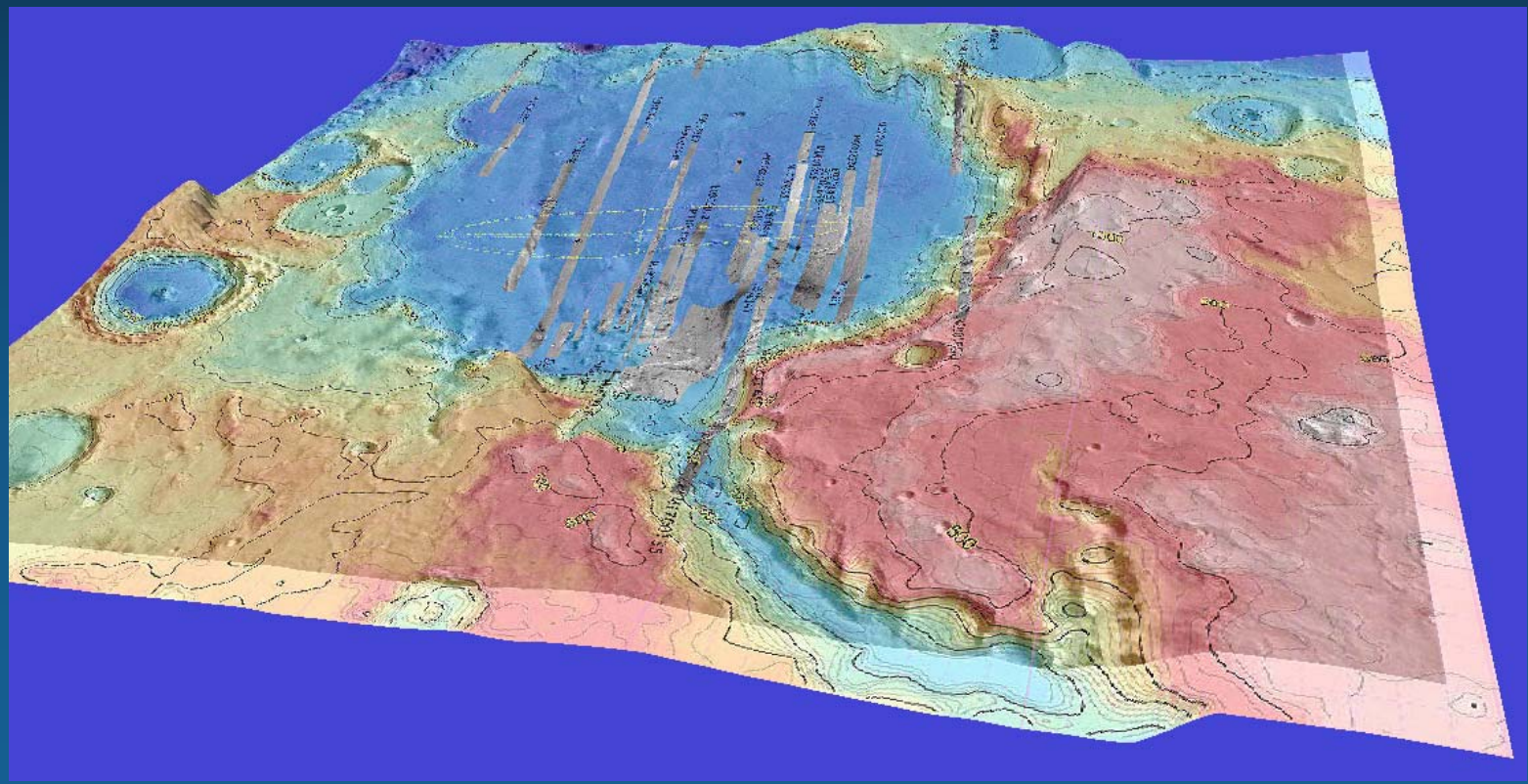
MOLA Track Atlas

- Mars Orbiter Laser Altimeter (MOLA)
- Plan and profile views of MOLA elevation data
- Users create and query profiles of MOLA tracks
- Multiple color-coding schemes



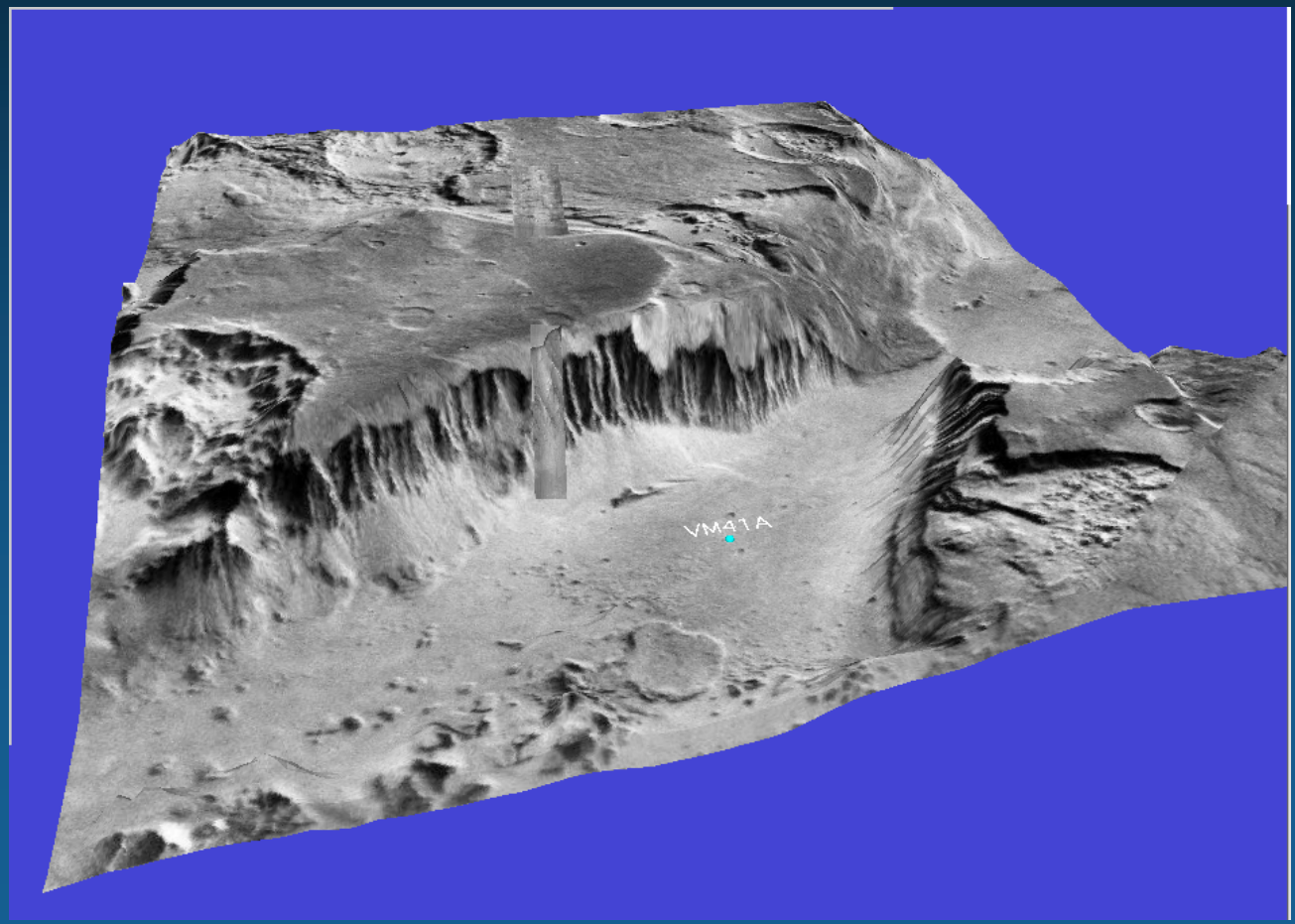
3D VRMLs of Landing Sites

- Available for top landing site candidates.
- Uses composite MOC/MOLA maps.
- Enables 3D user navigation (e.g. flyovers).



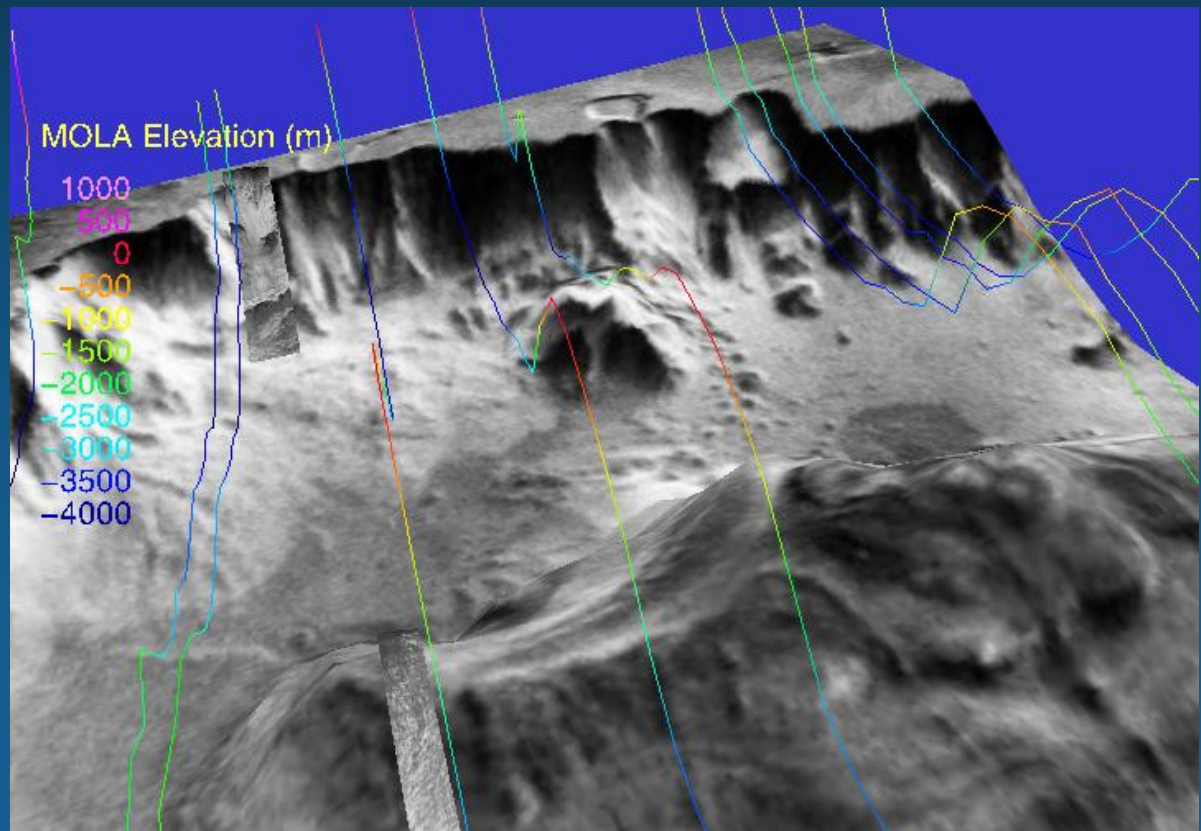
3D VRMLs of Equatorial Region

- 4° by 4° regions, from 15° N to 15° S
- Viking orbiter terrain data and surface images
- Mars Global Surveyor MOC images (embedded)

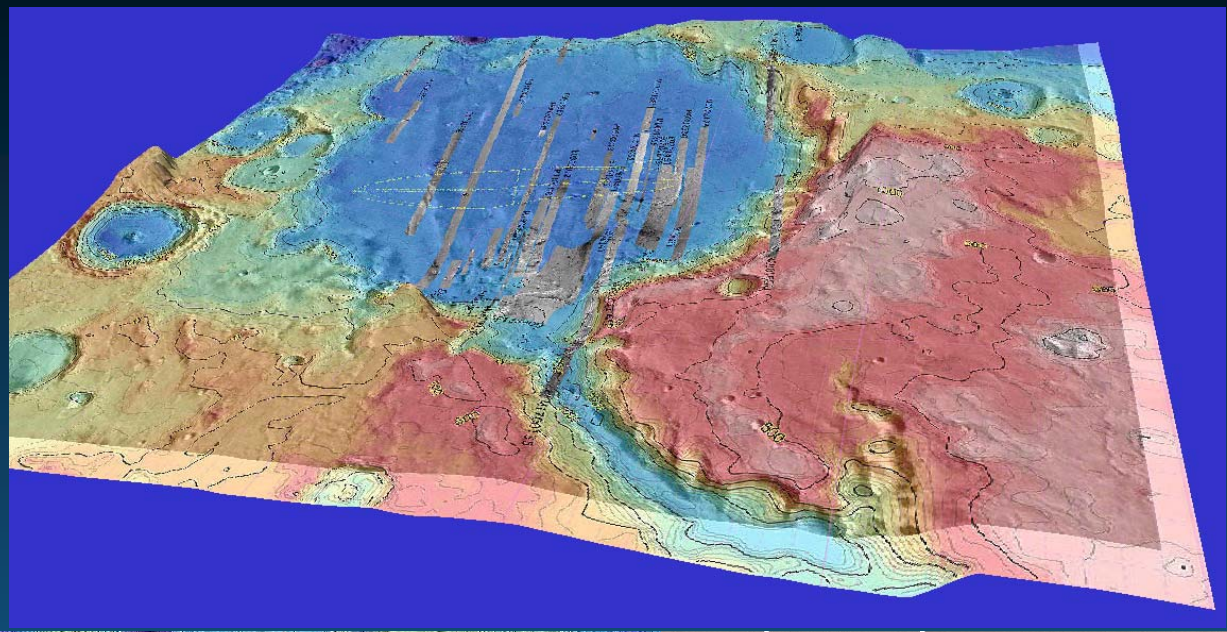


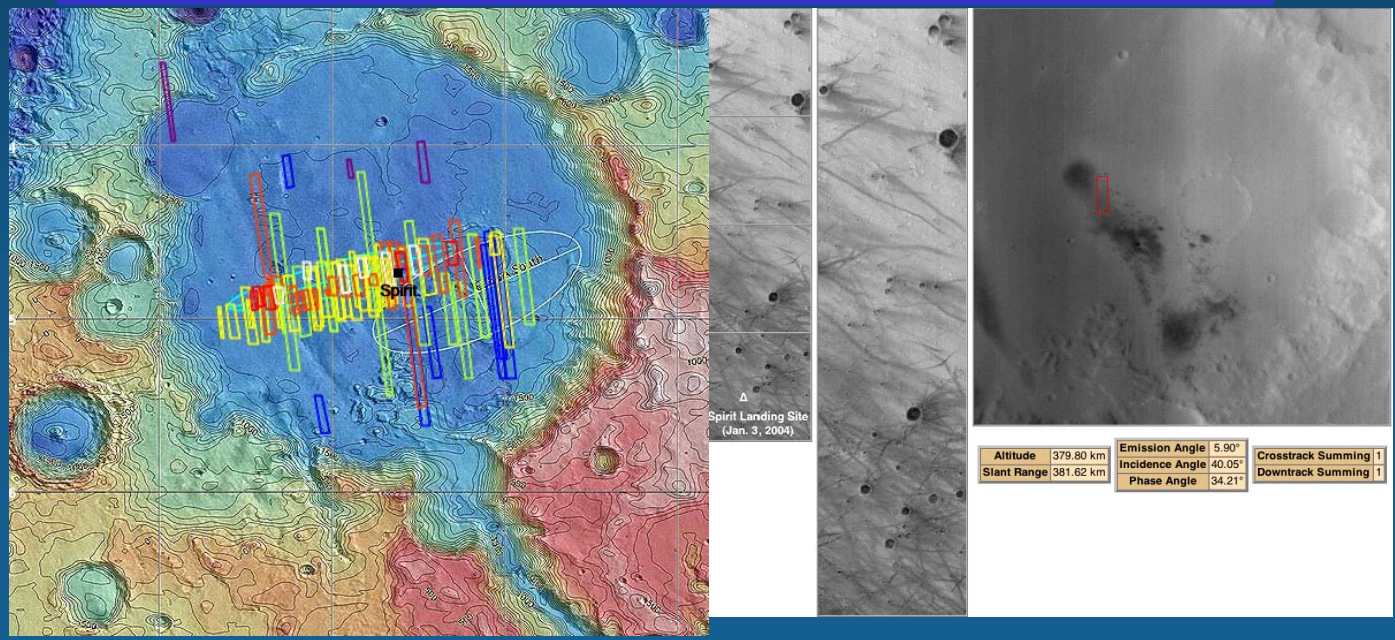
Automated Mars VRML Atlas

- Graphical selection of region-of-interest
- Java servlet constructs VRML using:
  - Viking Orbiter terrain data and images
  - MOC images (from Mars Global Surveyor)
  - MOLA elevation tracks (from Mars Global Surveyor)

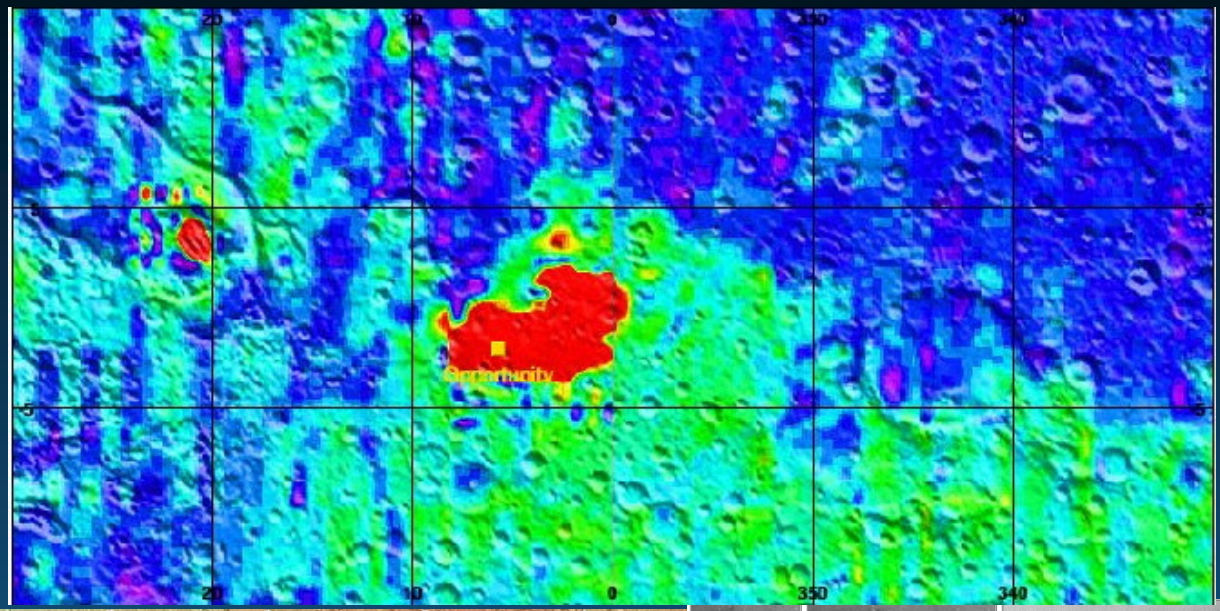


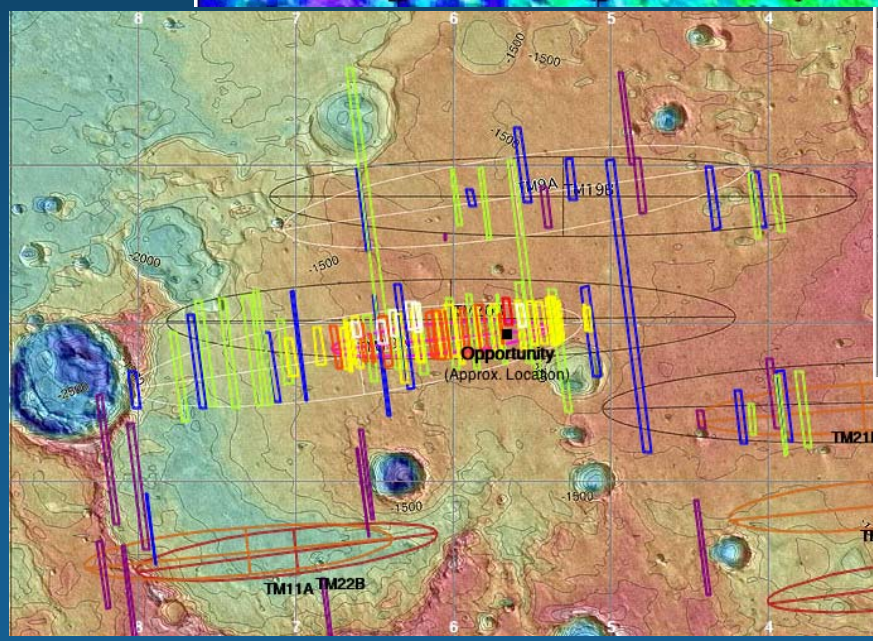
Marsoweb Tools: Gusev Crater

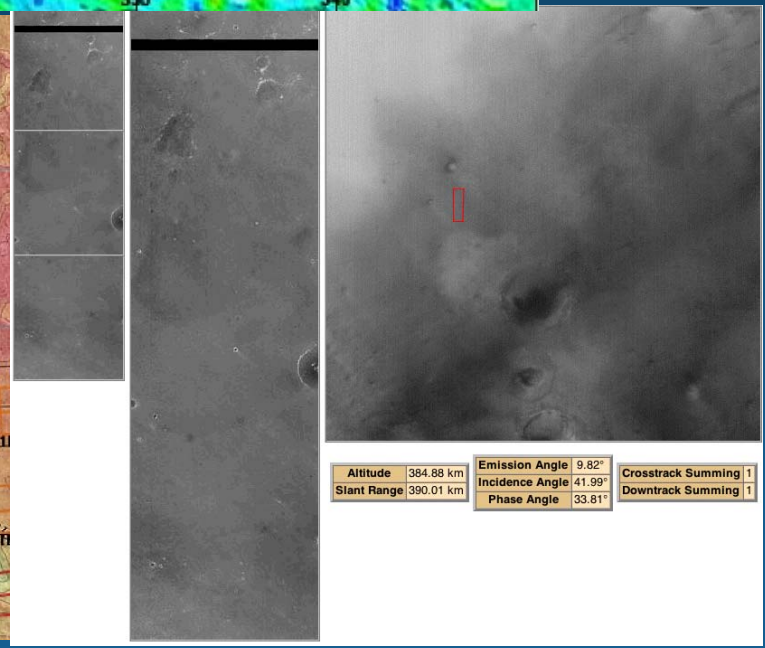




Marsoweb Tools: Meridiani







Mars Reconnaissance Orbiter 2005
HiRISE Camera

- HiRISE (High Resolution Imaging Science Experiment)
  - Ultra-high resolution (30 cm /pixel)
  - Stereo for 3D images
  - Multi-color

- HiWeb
  - Public interface to HiRISE.
  - Suggest imaging targets.
  - View HiRISE images
  - Extends Marsoweb technology.
  - Uses Mars image and data atlas for locating regions.

Marsoweb Impact

- In operation for over four years.
- Planetary scientists using it for research and publication.
- Has proven to be popular with the public as well (tens of thousands of individual users per month).
- Accessed from over 100 countries.
- Used in teacher workshops and class projects.
- Featured on TechTV's "ScreenSavers" program.
- Covered in recent NASA press release.

Skills Needed For This Field

- Strong interest and aptitude in math and science. (e.g. geology, astronomy, physics, chemistry)
- Good communication skills.
- Independent and self-motivated.
- For software engineers, strong interest & aptitude in computers.
  - Is increasingly true for scientists too.
  - NASA needs motivated scientists and computer technologists.
- College education is essential.